A CONSTANT CURRENT TERMINATION FOR CABLE LOCATING TONES

FIELD OF THE INVENTION

The present invention relates to the field of cable location and more particularly to the location of hidden or underground cables using a tone signal applied to the cable.

BACKGROUND

Telephone, cable television and other communication and control cables are often buried or placed in underground duct structures. For this type of cable placement, the most significant cause of cable outages is from dig ups by contractors. In an effort to minimize inadvertent dig ups, "call before you dig" programs are heavily promoted. The operating company must then be able to quickly and accurately locate and mark the buried cable.

Methods have been developed and are in commercial use which place in a locating tone on the cable armour or shield. A special receiver with magnetic field detecting coils is used to sense the tone current travelling along the cable. The strength of the received signal is directly proportional to the magnitude of the tone current in the cable sheath directly below the receiver.

The transmission circuit for the tone signals is formed by the metal armour or shield and insulated by the plastic cable jacket from earth which forms the return conductor. The circuit is basically a coaxial transmission path with the insulated cable armour forming the inner conductor and the surrounding earth forming the outer conductor.

The tone current must be present on all segments of a cable at a level greater than the minimum current dictated by the receiver sensitivity. This requires a termination at the end of the cable to draw at least the minimum amount of current. A

distribution cable typically has a number of branch cables which must also draw enough tone current for cable locating. Since the tone is heavily attenuated by the cable, the terminations near the source will load a much higher signal level than the distant terminations. To compensate for this, most installations use terminators with different signal load impedances for near, middle and far terminations. In addition to the inconvenience of using plural different impedance, the known systems require recalculation and replacement of the terminators when an additional branch is connected.

Where a cable is damaged, the tone signal level may fall below the minimum, making it difficult or impossible to locate the damaged cable.

SUMMARY

The present invention simplifies the terminator selection and mitigates problems created by the addition of branches and by cable damage.

According to one aspect of the present invention there is provided a constant current termination for cable locating tones, comprising:

a first terminal for connection to a tone conductor of a cable to be terminated;

a second terminal to be connected to a tone signal return path;

a load impedance connected between the first and second terminals; and

an active component responsive to variations in a voltage between the first and second terminals to vary the magnitude of the load impedance to maintain a substantially constant current through the load impedance.

According to another aspect of the present invention there is provided a tone locating system for a cable installation having a backbone cable, a plurality of branch cables, splices coupling the branch cables to the backbone cable and tone

conductors along the backbone and branch cables, the tone conductors being connected at the splices, the locating system comprising:

a tone source connected to the tone conductor of the backbone cable at an inner end of the backbone cable;

a plurality of terminations connected to the respective tone conductors at ends thereof remote from the tone source and the splices, each termination comprising:

a load impedance connected to the respective tone conductor and to a tone signal return path; and

an active component responsive to variations in a voltage between the respective tone conductor and the return path to vary the magnitude of the load impedance to maintain a substantially constant current through the load impedance.

The invention thus simplifies the terminator selection and installation by replacing all of the different fixed load terminators of the prior art with a single device. A termination according to the invention draws only enough tone current to ensure location of the cable. It is not affected by the signal strength. This has the additional benefit of allowing the location of a damaged cable when the tone signal level is below that for which a fixed terminator would have been designed. If branches are added later, the termination loads do not have to be recalculated and replaced as with fixed terminators.

In a preferred embodiment of the present invention, the termination circuit has an input terminal for connection to the tone conductor of the cable and an output terminal for connection to a ground return path. A lighting protection device, e.g. a gas tube surge suppresser, a MOV or both, bridges the two terminals. A l high pass filter is connected in series with the lighting protection to block low frequencies

used by either equipment on the same cable conductor. Also in series with the lighting protection and the high pass filter is a band stop filter for filtering induced mains frequency signals. The signal thus processed is delivered to a rectifier, the output of which is connected to a series circuit including the load resistor and a variable impedance, which is in the preferred embodiment the drain to source path of a field effect transistor (FET). The gate and source of the FET are connected across the load resistor. The FET regulates the gate - source voltage and therefore the current draw of the load resistor. A high frequency bypass filter bridges the source and drain terminals of the FET to prevent ringing since the FET may turn on and off very quickly around the current limit with very large input tones. A zener diode is connected in parallel with the load resistance to prevent damage to the FET from input surges.

Other embodiments of the invention are possible using other forms of current limiting circuit, for example a voltage regulator based circuit.

According to a further aspect of the invention there is provided a method of providing a controlled signal current on a cable having opposite inner and outer ends and a signal conductor along a cable between the inner and outer ends, said method comprising:

applying an electrical signal to the signal conductor adjacent the inner end of the cable;

providing a resistive termination at the outer end of the cable, connecting the signal conductor to a signal return path;

monitoring the electrical signal at the termination; and

maintaining a substantially constant electrical signal current at the termination by varying the resistive termination in response to variations in the electrical signal at the termination.

20. According to another aspect of the invention there is provided a method of providing a controlled signal current on each of a backbone cable with inner and outer ends and a signal conductor from the inner end to the outer end and a plurality of branch cables with respective inner and outer ends and with the inner ends spliced to the backbone cable, each of the branch cables having a signal conductor spliced at the inner end of the branch cable to the signal conductor of the backbone cable, the method comprising:

applying an electrical signal to the signal conductor at the inner end of the backbone cable;

providing resistive terminations at the outer end of the backbone cable and at the outer end of each branch cable, connecting the signal conductor to a signal return path;

monitoring the electrical signal at each termination; and

maintaining a substantially constant electrical signal current at each termination by varying the resistive termination in response to variations in the electrical signal at the termination.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings, which illustrate an exemplary embodiment of the present invention:

Figure 1 is a representation of an exemplary cable topology showing termination and ground leakage currents;

Figure 2 is a graph showing voltage and current draw waveforms;

Figure 3 is a circuit schematic of a termination according the present invention.

DETAILED DESCRIPTION

Referring to the accompanying drawings Figure 1 illustrate a cable

system 10 that includes a backbone cable 12 and branch cables 14. Each of these cables has a core 16, a metallic armour 18 surrounding the core and a plastic material outer jacket 20. The branch cables 14 are connected to the backbone cable and splices 22. In the illustrated embodiment, the armour 18 of the cables is connected at the splices to serve as electrically connected tone conductors.

At an inner end of the backbone cable is a tone source 24 that applies a tone signal to the tone conductor. This is transmitted down the conductor to a termination 26 at the outer end of each of the cables.

The transmitter 24 generates a tone on the cable system including the backbone cable 12 and the branch cables 14. The terminations, cable faults and cable capacitance to ground load down the signal. Loading of the signal is important because the current that flows generates a magnetic field around the cable. This radiated field is not blocked by the surrounding soil and is readily detectable several metres away. The locating receiver has a coil that is excited by the magnetic field and converts the field back into an electrical signal.

Signals other than the locate tone may be induced on the cable, from low frequency power line harmonics to broadcast radio frequency signals. The noise level, sensitivity of the receiver and the maximum buried depth of the cable set the minimum required tone current. The Biot-Savart law establishes the relationship of the magnetic field intensity (H), tone current (I) and cable depth (r). The factor a_0 is a constant. This equation is simplified for DC current, but the relationship is the same.

$$H = \frac{I}{2\pi r} a_0$$

In normal practice, the minimum locating current specified by the receiver sensitivity for cable depth of one to two metres is 5 ma. This assumes typical ground conditions and noise levels. For extra safety margin, the minimum locating

current on each segment should be 10 ma. Thus in Figure 1, currents i_1, i_2, i_3, i_4 and i_5 should be 10 ma. Some current, designated i_6, i_7 and i_8 in Figure 1 will be drawn by the cables' capacitive coupling to ground, especially with the higher frequency tones. Since the branches off the main cable may be very short and not have much capacitance, this current cannot be relied upon for locating all segments. When designing the tone source, this current has to be added to the maximum permissible fault current plus the number of terminations times the minimum locating current. The termination must draw the minimum locating current to ensure that no segment between the source and termination will carry less than the minimum current. In the example illustrated in Figure 1, the tone source must supply current equal to $i_1 + i_6$.. Current i_1 is in turn the summation of the remaining currents i_2 through i_5 as shown in the drawing.

The load of each of the terminations 26 must draw the minimum required location current regardless of the input voltage or tone frequency. The electrical schematic of each termination is illustrated in Figure 3. As shown in that drawing the termination has input terminals 28 and 30. Terminal 28 connects to the tone conductor of the cable while terminal 32 is connected to a ground return path. A lighting protection surge suppressor 32 is connected to the incoming signal wires to protect the termination from lightning.

The output terminal of the surge suppressor leads to a high pass filter 34 in the form of a large capacitor C1. Other equipment in the cable system may be connected to the cable sheath. This equipment generally operates at very low frequencies, much below the locating tones. The high pass filter 32 prevents interference with the other functions of the tone conductor so that when the locate tone is not applied, the termination will not load down the cable.

In series with the surge suppressor 32 and the high pass filter 34 is a

band stop filter 36. The tone conductor typically has induced AC voltages from power lines at significant levels relative to the locate tone. These induced voltages are also loaded by the termination and add to the drawn current. If the voltages are large enough, they cause the current to limit at the minimum locating current. If a tone signal arrives at the termination with the current already limited, there will be no current draw at the tone frequency. If current is not drawn at the correct frequency, the locating receiver will filter away the signal from the current that is drawn and will not be able to find the cable. The band stop filter 36 includes an inductor L1 and a capacitor C2 connected in parallel. The inductance and capacitance are calculated as follows:

$$freq = \frac{1}{2\pi\sqrt{LC}}$$

At the design frequency, normally 60hz or 50hz depending on the local mains frequency, the impedance of the inductor is equal and opposite to that of the capacitor. The currents are 180° out of phase and cancel each other out. For lower frequencies, the inductor shorts out the capacitor and for higher frequencies the inductor shorts out the inductor.

In series with the surge suppresser 34, high pass filter 34 and band stop filter 36 is a rectifier 38. This is a diode bridge composed of four diodes D1 to provide a full wave rectification of the AC tone signal applied to the terminals 28 and 30. The output of the rectifier 38 is connected to a series circuit including a load impedance 40 and an active component 42. The load impedance 40 is a resistor R1, while the active component is a field effect transistor Q1 with the gate and source terminals connected across the resistor R1 and its drain terminal connected to the rectifier 38. The full wave rectifier 38 is employed in this embodiment because the constant current regulator is a DC device and the incoming tones are AC.

The constant current regulator works by detecting the current through the load resistor R1 and limiting the current when it reaches a set threshold. It limits the current by increasing the series impedance of the circuit so that the load resistor R1 gets less current. The impedance in this case is controlled by the biasing the depletion mode FET Q1 so that its gate voltage decreases relative to the source voltage as the drawn current increases. This will limit the gate voltage to the gate threshold voltage because any more current would gradually turn off the transistor.

$$I_{\lim it} = \frac{V_{gs}}{R_{sense}}$$

Since the gate voltage is limited and the load resister is fixed, the drawn current I_{limit} is limited to:

The voltage V_{gs} is a specification of the depletion mode FET, so R1 is chosen to set I_{limit} to the minimum locate current.

The resulting current wave form is shown in Figure 2. It will look like the tone signal with the peaks chopped off because the current increases with the input tone voltage until the set current limit. The current stays at the limit until the tone input voltage comes back down. With a strong tone signal near the beginning of the cable, the current waveform will approach that of a sign wave. A square wave of current is acceptable because the tone receiver locating the cable will filter harmonics and only detect the fundamental frequency.

The fourier expansion for a square wave is given by:

$$f(x) = \frac{4}{\pi}\sum_{n=1,3,5...}\frac{1}{n}\sin\frac{n\pi x}{L} = \frac{4}{\pi}\sin\frac{\pi x}{L} + \frac{4}{\pi}\sum_{n=3,5,7...}\frac{1}{n}\sin\frac{n\pi x}{L}$$

This indicates that the peak amplitude of the first harmonic (n=1) will be $4/\pi$ times greater than the square wave peak. The peak of the sign wave must then be converted to an RMS value as follows:

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{4/\pi}{\sqrt{2}} = 0.900$$

With the tone current being 0.900 of the current limit, the calculations for the current limit will have to be 1/.9 or 11% higher than the minimum desired locate current.

In use of the termination illustrated in Figure 3, the lightning protector 32 protects the circuit from lightning. The capacitor C1 blocks DC and passes AC signals including the tone signal. The band stop filter 36 blocks any induced mains frequency currents. The rectifier 38 rectifies the incoming signal because the following current regulator is limited to one polarity. The field effect transistor Q1 regulates the gate to source voltage across the load resistor R1 to about 1.77 volts. The minimum locate current of 10 ma results in a maximum current limit set to 11.1 ma from the 11% correction calculated above. The value for the load resistor R1 is calculated as the gate to source voltage divided by the current limit. The high frequency bypass capacitor C3 prevents ringing as the FET would turn on and off very quickly around the current limit with very large input tones. The zener diode D2 clamps the gate voltage to a tolerable limit, say 5 volts, to prevent damage to FET Q1.

With this circuit tolerances may be quite large for the inductor L1 and some tuning of the capacitor C2 may be required to centre the band filter at 60 Hz or 50 Hz as the case may be.

While one embodiment of the present invention has been described in the foregoing, it is to be understood that other embodiments are possible within the scope of the invention. For example, various different forms of constant current regulator may be employed. It is for example, possible to produce a regulator for both polarities, thus eliminating the rectifier. Voltage regulator based limiters, can for example, be used. The invention is therefore to be considered limited solely by the

scope of the appended claims.